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Prototype design and analysis of a mobile robot

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Keywords: mobile robot, design, robot arm.
Abstract: Mobile robots are robots that can move on their own. Robots move in their environment, not fixed to a real location. With the flexibility of the navigation wheel combined with the dynamic system, the wheeled mobile robot is suitable for flexible movement on flat terrain, using tank-like tracks will be suitable for moving on difficult, complex, bumpy terrain. The article introduces a process of developing, designing a mobile robot combining a 4-degree-of-freedom arm with a mobile chassis. Kinematics, dynamics, strength of structure testing and simulation are all calculated in detail. Finally, a prototype was built and tested to prove the correctness of the process. The project has calculated the kinematics and dynamics of the model, thereby building trajectories, designing controllers for the vehicle and manipulator, thereby simulating problems on Matlab-Simulink. Designing 3D CAD models, building hardware, and testing CAE durability on Abaqus software. The results are visually tested by software, with high feasibility, is the premise for manufacturing.

1 Introduction

Industrial robots are robots designed to work in industrial production environments. Robots have been and are an indispensable part of production. Robots help increase productivity, save space, reduce labor costs, improve quality and labor safety [1-6].

Mobile robots are robots that can move on their own. Robots move in their environment, not fixed to a real location [7-9]. Mobile robots are different from industrial robots that are usually placed near fixed and operate with arms, mobile robots are capable of performing tasks in many different locations instead of being fixed in one place like other types of robots. With the flexibility of the navigation wheel combined with the dynamic system, the wheeled mobile robot is suitable for flexible movement on flat terrain, using tank-like tracks will be suitable for moving on difficult, complex, bumpy terrain.

Currently, the world has been developing mobile arm robot lines to perform many different tasks such as: flexible navigation and automatic movement of the robot to the required place accurately and safely or automatic navigation of parts. The most common type of robot arm that performs the function of picking and placing objects in industrial production[10-14]. This robot arm will pick up objects from one position and drop them at another position. The farther the distance between these two positions, the larger the requirement for the arm size, leading to high manufacturing costs. Therefore, combining a mobile cart with a pick and place robot arm is an ideal combination, increasing the working space of the robot arm.

The article introduces a process of developing, designing and manufacturing a mobile robot combining a 4-degree-of-freedom arm with a mobile chassis. Kinematics, dynamics, strength of structure testing and simulation are all calculated in detail. Finally, a prototype was built and tested to prove the correctness of the process.

2 Methodology

2.1 Kinetic of wheel mobile

Figure 1 shows the basic structure of a mobile robot, consisting of two main parts: a mobile vehicle combined with a 4-degree-of-freedom robot arm. Mobile robot kinematics is the most basic problem of how a robot system works.

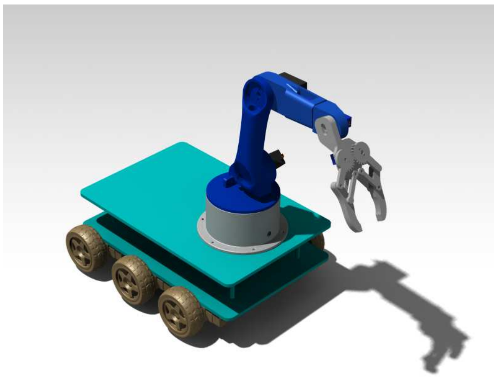

Figure1 Mobile robot CAD modelling

The kinematic equations will give the relationships between the control parameters and build the robot's state in space, the way the robot moves without considering the impact force (1).

$$v = \frac{(v_r + v_l)}{2} \ and \ \omega = \frac{(v_r - v_l)}{L} \quad (1)$$

In which:
v_l – velocity of the left wheel,
v_r – velocity of the right wheel,
L – distance between the 2 wheels,
R – Wheel radius.

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From there the instantaneous radius of curvature of the trajectory is calculated by the equation (2):

$$R = \frac{L.(v_r+v_l)}{2.(v_r-v_l)} \tag{2}$$

2.2 *Mobile trajectory simulation*

The motion trajectory is described as in Figure 2, including 2 straight motions and 1 curved motion.

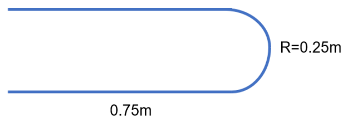

Figure 2 Mobile robot trajectory

Time motion on a half of circle (3), (4):

$$\boldsymbol{t} = \frac{s}{v} = \frac{\pi.R}{(v_r+v_l)/2} = \frac{0.225.\pi}{(0.1+0.05)/2} = \boldsymbol{9.43s} \tag{3}$$

Time on straight line $\boldsymbol{t} = \frac{0.5}{(v_r+v_l)/2} = \boldsymbol{10s}$ (4)

Conduct orbital movement model creation and simulation, the results obtained are as described in Figure 3, the results are consistent with the calculation.

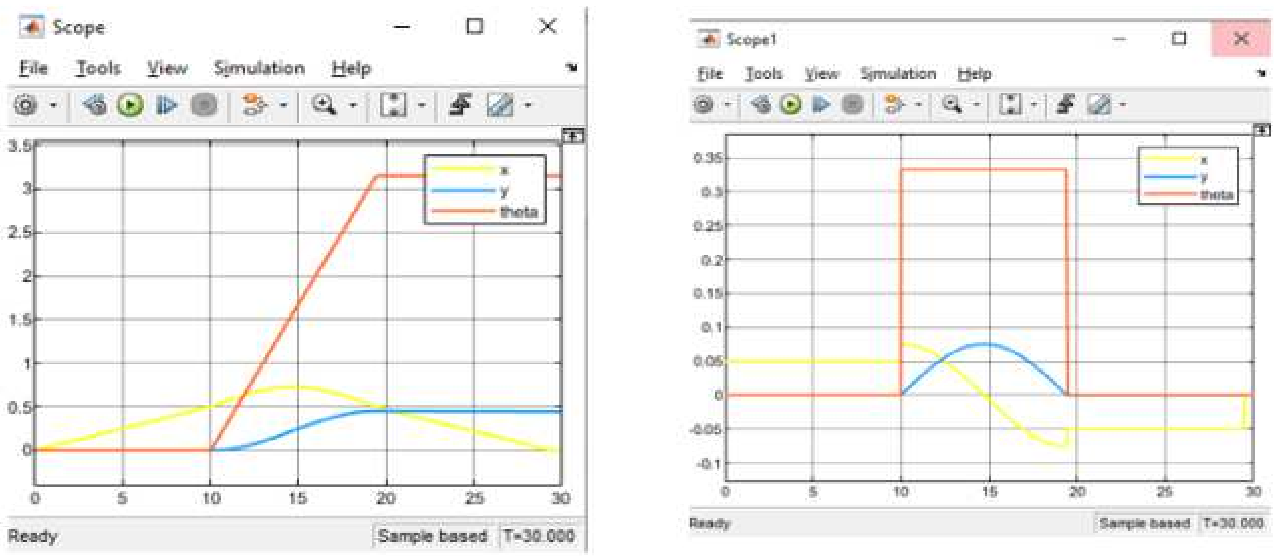

Figure 3 Velocity simulation

After calculating the velocity problems, the robot's motion trajectory is calculated as shown in Figure 4. The motion trajectories in the X, Y and angle directions are all calculated, with the aim of providing the robot's working space.

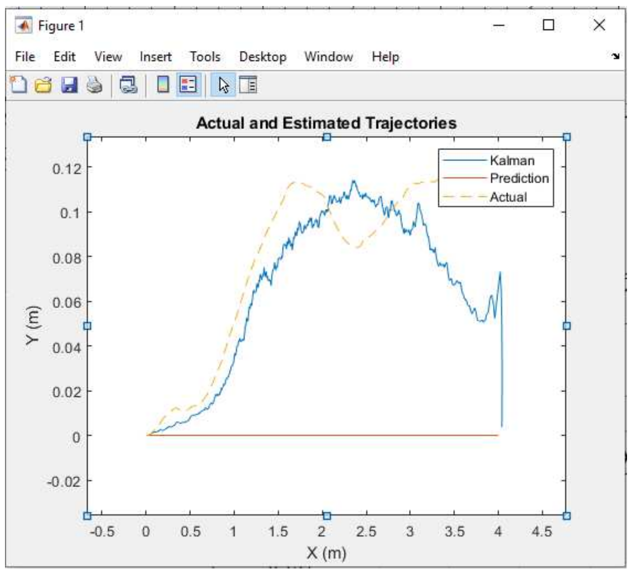

Figure 4 Investigating robot trajectory through simulation

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2.3 *Robot arm modelling*

Figure 5 shows the 4-degree-of-freedom robot arm mounted on the chassis. The arm's kinematics, dynamics and workspace are shown in Figure 6, Figure 7, Figure 8 and Figure 9. The reversible, velocity and position problems are all considered in detail.

Figure 5 Robot arm CAD model

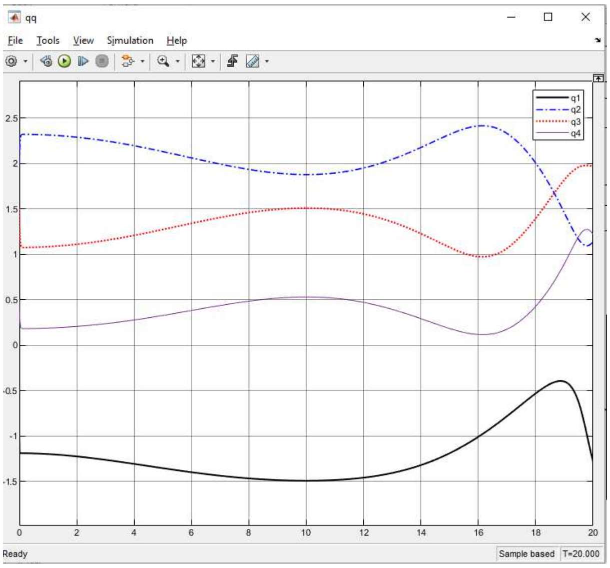

Figure 6 DH parameter values

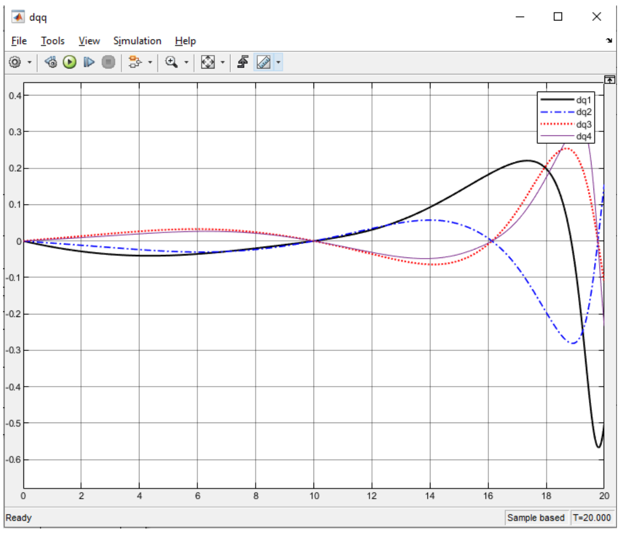

Figure 7 The velocity value diagram process

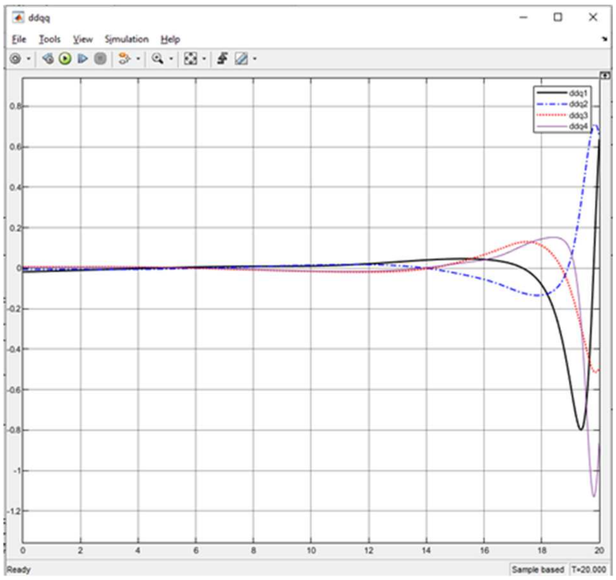

Figure 8 The acceleration value diagram process

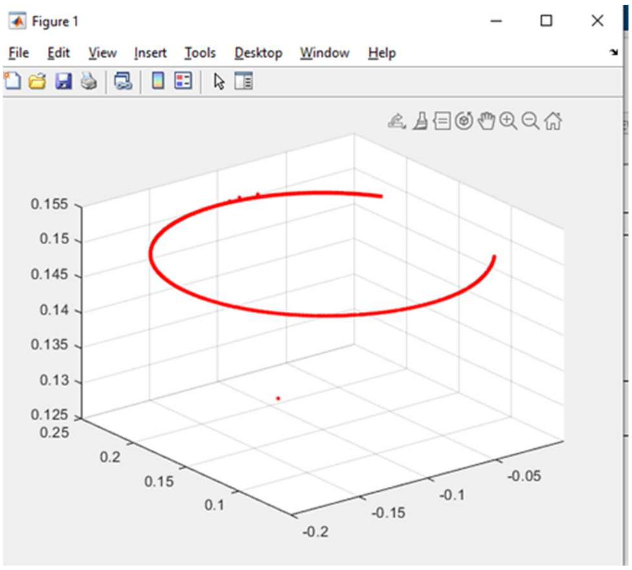

Figure 9 Robot trajectory in the workspace

The robot arm model is 75 cm high, 30 cm long and 25 cm wide, with a total mass of 3 kg. The robot is capable of picking up objects weighing 200 g.

2.4 *Strength of structure testing*

Strength testing is a necessary step to ensure the system works stably before it can be manufactured, this is an important step in any design of any machine.

Figure 10 shows that the shear stress on the wheel motor is mainly concentrated at the end of the motor and the end of the wheel joint attached to the motor. The stress is in the range from 400Pa to 700Pa. As for the frame, the shear stress is mainly concentrated at the lower layer of the frame and the end of the lower connecting rod is subjected to the highest pressure in the range of 700 to 1000 Pa.

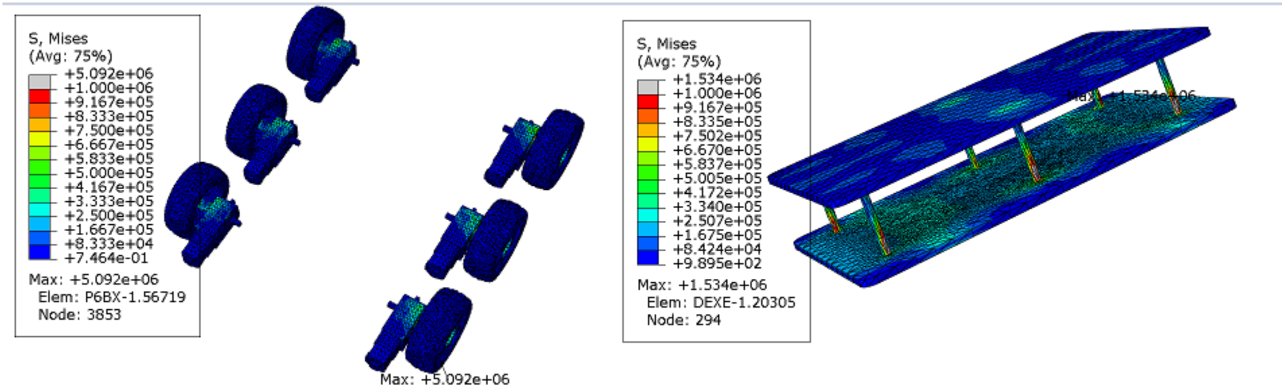

Figure 10 Tensile stress simulation on wheel and frame

Figure 11 shows that the normal stress on the wheel motor is concentrated mostly at the wheel-motor connection area in the range of 60Pa to 200 Pa. As for the frame, it is mainly concentrated on the bottom surface and at the contact part of the connecting rod in the range of 200Pa to 500Pa.

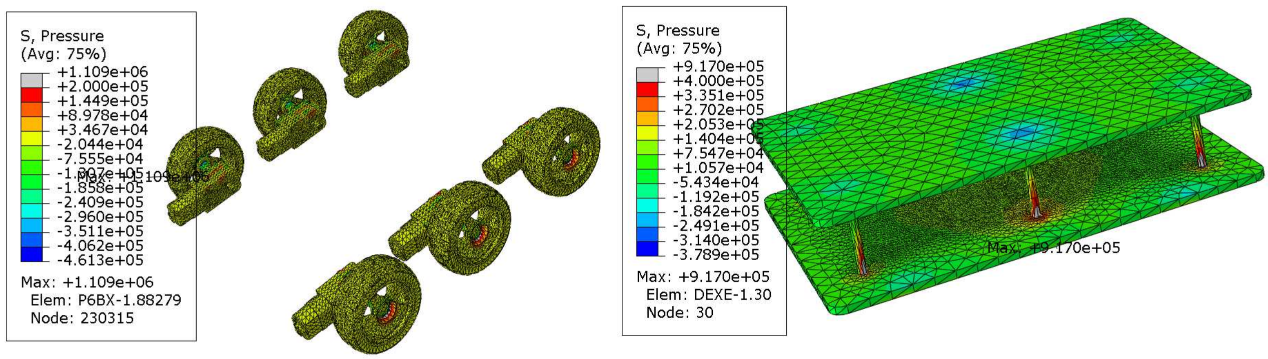

Figure 11 Shear stress simulation on wheel and frame

Figure 12 shows that the displacement at the engine wheel and the chassis increases from the inside out. The maximum value is reached at the end with the displacement value. As for the chassis, the maximum displacement value reaches 1.28cm at the two ends of the chassis. From the durability tests for the chassis structure, it is found that the chassis structure is completely strength enough to ensure working capacity.

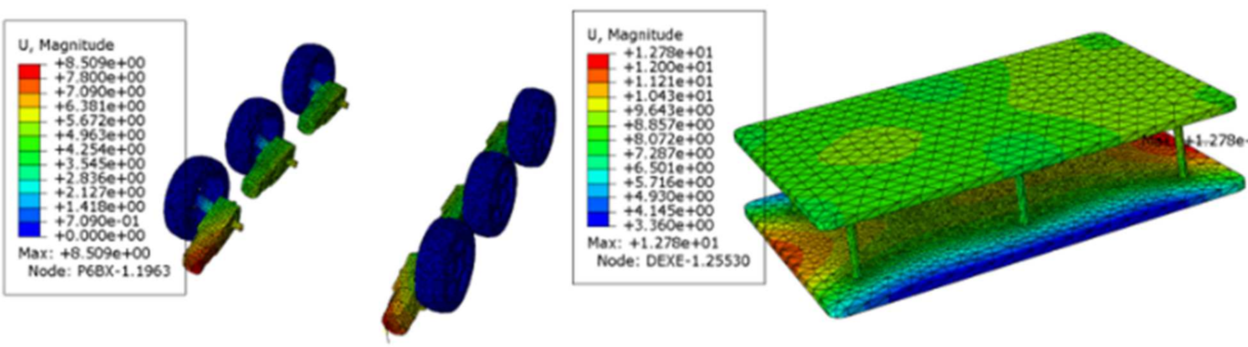

Figure 12 Displacement higher on wheel and frame

3 Result and discussion

Figure 13 shows an overview of the proposed mobile robot model. Capable of picking up objects up to 0.4 kg, the vehicle is capable of moving straight and at an angle. Overall assessment of the model is complete and meets the criteria for a mobile robot model combining a four-link manipulator capable of recognizing objects. However, the accuracy and operating time can be further improved to help the model become more complete.

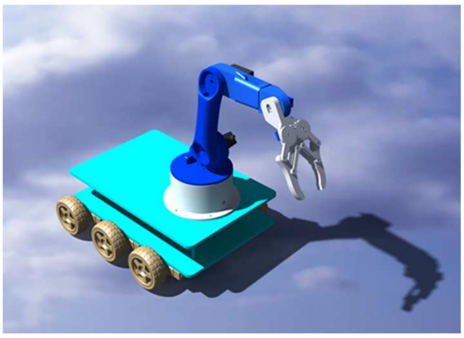

Figure 13 Mobile robot construction

4 Conclusions

The article proposed a research process to build and implement a mobile robot combined with a 4-degree-of-freedom manipulator. Capable of picking up objects up to 0.4 kg, the vehicle is capable of moving straight and at an angle., The time to perform a pick and place cycle is about 50 seconds. The project has calculated the kinematics and dynamics of the model, thereby building trajectories, designing controllers for the vehicle and manipulator, thereby simulating problems on Matlab-Simulink. Designing 3D CAD models, building hardware, and testing CAE durability on Abaqus software. A mobile robot prototype has been designed and developed. The mechanical components have been presented. Dynamic analyses have been performed to model the system operation. The developed prototype has proven to be reliable and stable and can be manufactured in future works. The results are visually tested by software, with high feasibility, is the premise for manufacturing.

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